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VI. *Experiments on the influence of the Aurora Borealis on the magnetic needle.*

By the Reverend JAMES FARQUHARSON, F.R.S. Minister of Alford, Aberdeenshire. In letters addressed to Captain EDWARD SABINE, Secretary of the Royal Society.

Read January 28, March 4, and April 1, 1830.

Alford, December 15th, 1829.—THE apparatus, belonging to the Royal Society, with which these experiments were made, consists of a horizontal brass circle, about one foot in diameter, graduated to divisions of 10 minutes, and capable of adjustment to a perfect level by means of spirit levels and screwed feet. Concentrically within this divided circle moves a circular horizontal brass plate, its edge touching the divisions, and having at opposite points two verniers, which, by means of attached microscopes, indicate the movements which it makes to 60th parts of 10 minutes, or 10". The movement of the plate within the circle is effected by means of a screw. A circular brass needle-box is attached to the surface of the inner plate, and a vertical pointed steel wire for supporting the needle forms the centre. At opposite points in the needle-box are fixed two micrometers with cross wires in the foci, for adjusting the needle to a level, and observing any change in its direction. The top of the needle-box is a circular plate of ground glass in a brass ring, made to slip easily off and on, and having screwed into its centre a vertical brass tube about 8 inches long, for the purpose of suspending the needle with fibres of silk, for measuring the time of its oscillations. A horizontal brass pin, with a minute perforation for the silk near its middle, passes through the vertical tube near its top, and being contrived with several motions, serves to adjust the suspended needle, and bring it correctly over the steel point, where its levelling can be completely ascertained.

The magnetic needle itself is a rectangular plate about 5 inches long, half an inch broad, and $\frac{1}{16}$ th of an inch thick. An agate cup set in brass admits of being screwed in either at the narrow or flat side of the needle; and a little fixt ring of brass, with a minute perforation in its top, rising over the cup,

admits of the ready attachment of the silk ; so that the needle can be placed on the steel point or suspended with the silk, with its flat face either vertical or horizontal.

This apparatus measures, with great accuracy, very minute changes in the declination of the needle. A change as small as $10''$ is quite sensible by it. It was placed on a firm-set table, in a room of my house, on the 21st of September last; and by shifting the whole apparatus, the cross wires of the micrometers were brought into a line with the needle, when at rest at 8 o'clock in the evening ; the index of the vernier being at the same time brought to zero on the divided circle. The readings of the variations of the needle are therefore reckoned from its position at that hour, which was made choice of as being that when the Aurora borealis was most likely to appear, and thus the diurnal variation would be brought to interfere as little as possible with any variation induced by that meteor.

The needle, where it is stationed, is subjected to some influence from several fixt pieces of iron, but not to any from iron that is moved from place to place. There was a necessity for removing the apparatus temporarily from its station on the 24th of November ; but it was carefully replaced on the 2nd of December ; marks having been made in the floor for the feet of the table, and on the table for the feet of the apparatus ; and the cross wires brought to the line of the needle at 8 P. M. as before.

In making observations on the intensity, the time occupied by a certain number of horizontal vibrations of the suspended needle is measured by a stop-watch, the character of which it is necessary to describe. It is a time-keeper, on which, indeed, not much reliance ought to be placed, if it were necessary to have the intervals estimated in absolute mean time ; as, although it is adjusted to return nearly to mean time at the end of every twenty-four hours, when only wound up once during that period, yet it goes very unsteadily at many of the intermediate hours. I have found, however, that it keeps time nearly with a well-regulated pendulum clock, from 12 minutes after it is wound up till about an hour after that time. It is therefore always prepared for the observations by being stopped 12 minutes after it is wound up ; and thus, although the intensities measured by it could not very safely be compared with those measured by a more correct watch, yet considerable reliance may be

placed on the comparison of measures thus made by itself at different times. I have in fact already discovered, by using these precautions, such an increase of intensity as was to be anticipated during the cold season now come on. My observations have been too desultory, owing to numerous other avocations, to permit me to look out for a diurnal change of intensity.

The balance of the watch makes 290 vibrations in a minute, so that the vibrations are not commensurate to the seconds; recourse therefore must be had to reading off the time by approximation on the seconds dial-plate. The time is estimated to the nearest quarter of a second by means of a microscope, and the watch relieved from the point where it stops for a new observation; thus neutralizing any incorrectness in the reading off, and any inequality in the divisions of the dial-plate on the principle of the repeating circle. The stop is on the balance of the watch, and is therefore instantaneous.

After trials of various arcs, I have found it most convenient, for insuring that the different series of observations shall commence in equal arcs, to make the needle vibrate by its own breadth at the extremity, that is, in arcs of nearly 12° , which is correctly determined when the corners of the needle come alternately to the cross wires of the micrometer. The watch is relieved the instant the centre of the needle comes to the cross wires the third time after the extent of the arc has been noted by the corners; 50 oscillations are then reckoned, and the watch stopped for reading off the time. A very small piece of iron is employed for moving the needle, which is instantly deposited at some distance at right angles to it; and for night observations my candlestick is of glass.

I had no leisure for making observations on the intensity for several days previous to the 14th of December. The last I made were on the 2nd, 3rd, and 4th of December,—4 sets of 50 oscillations each day at 8 P.M.; average of each set, and of the whole, in $225''.25$: Therm. from 35° to 42° .

I shall now copy from my journal the observations of the 14th of December. They were set down at the time, at intervals of a quarter of an hour.

5 $\frac{3}{4}$ P.M.—Aurora seen in various quarters of the sky.

6 P.M.—Arch of nebulous light in N. about 25° high; another S. about 30° high; vertex of each about the mag. mer.: S. arch just over a continued line of clouds. Many detached clouds in region of N. arch.

Sky between these quite clear of clouds, with many brilliant streamers of Aurora, forming evidently parts of two fringes coming towards the zenith from N. Bar. 30° , Therm. 39° ; nearly calm.

6 $\frac{1}{4}$ P. M.—Many groups of very brilliant short streamers now passing into the zenith. Needle on steel point 2' W. Intensity, 1st set of 50 oscill. in 225".25; 2nd in 225".25; 3rd in 225".

6 $\frac{1}{2}$.—Narrow arch near the zenith, very faint, and small clouds appearing there. Arch in the S. descending to the horizon, and clouds descending with it. That in the N. now about 35° high, accompanied by many clouds. Needle on steel point shifted to 5' E.

6 $\frac{3}{4}$.—Needle on steel point now 23' E. S. arch now extinct. N. one about 45° high; nebulous lights under it, and clouds rising with it.

7 P. M.—Needle on steel point slowly returning westward.

7 $\frac{1}{4}$.—Needle at zero.

7 $\frac{1}{2}$.—Needle 4' W. Aurora still forming an arch at N.; but not advancing higher than 45° .

7 $\frac{3}{4}$.—Needle still 4' W. Several arches of nebulous light in N. under 45° , with many clouds; gentle gale a point or two S. of W.

8 P. M.—Arch of nebulous light again formed at S. about 45° high. W. and middle parts of N. arches expiring as they reach 45° ; but their E. ends going now much further S. and passing the prime vertical to the mag. meridian; not fully seen, however, for clouds, which are following the Aurora in all its flittings; the rest of the heavens being quite clear. Needle on steel point now 7' 50" E. Intensity, 1st in 225".25; 2nd in 225".25. Therm. 38° .

8 $\frac{1}{4}$.—Needle on steel point 13' 40" E.

8 $\frac{1}{2}$.—Needle on steel point 8' 50" E. Intensity, 1st in 225".25; 2nd in 225".25. Nebulous light at N.W. and very brilliant groups of streamers at N.E. Aurora in the S. now extinct.

8 $\frac{3}{4}$.—Aurora fading; needle on steel point 4' 20" E.

9 P. M.—Intensity, 1st in 225".25; 2nd in 225".25. Needle on steel point 2' E.

9 $\frac{1}{4}$.—Three arches of Aurora of unusual brilliancy at mag. N. coming up rapidly with most splendid streamers. Fragments of the uppermost soon passed the zenith, and needle shifted slowly to 19' W.

- 9½ P. M.—Very obscure narrow nebulous arches across the zenith, and a little S. of it at right angles to mag. mer. ; being the remains of some of the arches seen at 9¼. Needle shifted to 9' 50" E.
- 9¾.—Only a few streamers near N. mag. mer. 25° high. Needle now 12' E.
- 10 P. M.—Very brilliant arch of streamers in N. about 25° high ; and narrow obscure arch across mag. mer. a little S. of zenith. Needle 14' E. Intensity, 1st in 225".25 ; 2nd in 225".25. Therm. 37°. No clouds.
- 10¼.—Arch of streamers in N. about 25° high, not very brilliant. Many groups of faint streamers higher up ; and nebulous narrow belts of pale light across the zenith and southward of it a little, at right angles to mag. mer. These are all expiring as they go S. in succession. Needle shifted as I was watching it from 14' E. to 3' W. in the space of about 6 minutes.
- 10½.—Many groups of very pale streamers over all the northern half of the sky, and the western half of a very pale zenith arch has passed to about 20° S. of the zenith. Needle now 21' 30" W. Intensity, 1st in 225".5 ; 2nd in 225".75. Therm. 35°.
- 10¾.—Aurora nearly faded every where, and heavy clouds forming in N.W. Needle returned to 3' W.
- 11 P. M.—Aurora extinct. Needle at 5' W.
- 12 P. M. Nebulous light at the horizon in mag. N. has continued for nearly an hour, fading at 10° high, and rising again from the hills. Needle 1' E. and has remained so for three quarters of an hour. Many falling stars whose paths are parallel to the lines of the streamers, or at right angles to them in the planes of the fringes. Intensity, 1st in 225".5 ; 2nd in 225".25. Breeze a point or two S. of W.
- December 15, 1 P. M.—Intensity, 1st in 225".25 ; 2nd in 225".5. Therm. 34°.
- It ought to have been stated, that from noon on the 10th of December till the evening of the 14th, there was a continued series of the hardest gales at S.W. and W. that have occurred this autumn.

It is obvious from the above detail, that the disturbance of the magnetic declination by the northern lights on the evening of the 14th of December was so great, and so frequently reversed from E. to W., and the contrary, as to leave no shadow of doubt regarding the reality of the phenomenon. It is to be ob-

served, however, that no disturbance took place till the fringes of the Aurora had gone so far south as to place the needle in their planes, or in the line of prolongation of the middle or most elevated streamers of the fringes, which is that of the dipping needle. The numerous observations formerly made by me this autumn, of which I have already put you in possession*, and those also

* 10th of October.—11 A. M. Series of 50 oscillations: 1st in $227''.75$; 2nd in $227''.5$; 3rd in $227''.2$; 4th in $227''.5$; 5th in $227''.75$; 6th in $227''.5$.

2 P. M.—1st in $227''.5$; 2nd in $227''.5$.

4 P. M.—1st in $227''.75$; 2nd in $227''.5$.

11th of October.— $6\frac{1}{2}$ P. M.—Very brilliant streamers seen, at an opening among clouds at N. W. reaching upwards to about 35° . Series of 50 oscillations: 1st in $227''.75$; 2nd in $227''.5$; 3rd in $227''.5$; 4th in $227''.75$.

$7\frac{1}{2}$ P. M.—Column of very brilliant light near the horizon at the W. extremity of the prime vertical to the mag. mer. and arches of Aurora in the N. Series of 50 oscillations: 1st in $227''.5$; 2nd in $227''.75$; 3rd in $227''.5$; 4th in $227''.25$.

It is evident that the differences between the averages of these series at the several periods, are within the limits of the probable errors of observation; so that the intensity was not sensibly affected by the Aurora.

At 8 P. M. the needle on the steel point remained steady at its usual position at that hour.

At 20 minutes past 8, needle on the steel point was still steady, with many brilliant groups of streamers in the N. and an arch of light below them, and another bright column at mag. W.

On the 25th of October the Aurora again appeared; but neither at this time could I find that either the intensity or direction of the needle were altered.

17th of November.—3 P. M. 50 oscillations: 1st in $225''.75$; 2nd in $225''.5$; 3rd in $226''.25$; 4th in $226''$.

$6\frac{1}{4}$ P. M.—A complete arch of pale nebulous light, with its vertex about 20° high at mag. mer. Intensity, 1st in $225''.25$; 2nd in $225''.25$. Needle on steel point steady at its usual place at 8 P. M.: and intensity, 1st in $225''.5$; 2nd in $225''.5$.

A succession of arches rose one below another, and successively expired at about an elevation of 20° till 11 P. M. when the western end of one of them became unusually brilliant, and dense. Streamers. Intensity at this hour, 1st in $225''.5$; 2nd in $225''.75$; 3rd in $225''.5$. Needle has now $3'$ E. var. from its position at 8 P. M. At 12 P. M. Intensity 1st in $225''.25$; 2nd in $225''.25$. Var. $3'$ E.

On the 18th of November, Aurora first seen at 6 P. M. At 8 P. M. with a very brilliant arch about 20° high, and a few streamers, the remains of a preceding one, about 35° high. Intensity, 1st in $225''.25$; 2nd in $225''$; 3rd in $225''.5$; 4th in $225''.5$. Variation at 8 P. M. $2'$ E.—At $9\frac{1}{2}$ P. M.; Intensity 1st in $225''.25$; 2nd in $225''$.—At 10 P. M. Var. $4'$ E.—At $11\frac{1}{2}$, Var. $3'$ $20''$ E.

19th of November.—At 2 P. M.; Intensity observed, 1st in $225''$; 2nd in $225''$; 3rd in $225''$; 4th in $225''.25$.

At 8 P. M. Aurora first seen. A pale light through many clouds about 15° high. Variation not altered. Intensity, 1st in $225''$; 2nd in $225''.25$.

[The variations at 11 and 12 P. M. of the 17th of November, and at 8, 10, and $11\frac{1}{2}$ P. M. of the 18th of November, were within the limits of the irregularities of the diurnal variation.]

now detailed, afford a proof,—a negative one indeed, and therefore imperfect, but now very extensive,—that the needle is not affected by the Aurora, till it comes into the plane of the dip: and we have thus, I trust, an explanation of the discordant results obtained and announced regarding this matter by different former observers. When the disturbance has been observed, there have been no doubt zones of Aurora in the plane of the dip, though perhaps obscure and liable to be overlooked. Most of those I observed in that position on the 14th were so faint, that I might not have noticed some of them, had I not traced their progress southward from stations where they were much more brilliant.

It would be as yet premature to infer any connection between the easting and westing of the declination, and the vividness of the fringes in their eastern or western ends. What occurred at 8 P. M. and $\frac{1}{2}$ past 10 P. M. might lead us to suspect that the needle declines towards the most vivid end.

In regard to the intensity, I cannot venture to say, that the slight decrease indicated at $\frac{1}{2}$ past 10 is not an error of observation; being conscious that the limits of errors of this kind ought not to be taken at less than the change then noted. I could not take the intensity at $\frac{3}{4}$ past 6, when the declination was greatest, from a desire to watch the extent of the change in declination produced by the Aurora, of which I was for the first time fully assured. When I receive the separate apparatus for the intensity, with which I am to be favoured, I shall expect more certain results on that point.

Alford, December 26th, 1829.—Since I addressed you on the 15th current, I have made some additional observations on the Aurora borealis, of which I proceed to put you in possession in continuation.

From Journal of observations.

Frost during the 16th, 17th, and 18th Dec. Therm. at night 19°.

19th Dec.—10 P. M. Bar. 29°.7. Therm. 30°.—At $\frac{1}{2}$ past 11 P. M. a heavy low fog cleared up, and exposed a very brilliant Aurora. An arch of very brilliant streamers about 25° high over dense clouds in the N. A broad lane of clear sky above these from W. to N. E. Over head many broken clouds giving partial views of a narrow arch of Aurora from E. to W. in the plane of the mag. dip, and many streamers approaching the zenith from N. To the S.

of these another clear lane of sky E. and W. and nebulous Aurora over dense clouds at S. horizon. Needle on steel point $36' 20''$ E. Before the watch was prepared for the intensity, needle shifted to only $33'$ E. Intensity then found 50 oscillations in $226''.25$. Needle at conclusion of the observation $14'$ E. —12 P. M. Another arch getting into plane of the dip, the rest of the Aurora presenting nearly the same appearances as before. Needle shifted to $22'$ E. Intensity 50 oscil. 1st in $225''.5$; 2nd in $225''.5$. Therm. still 30° . Needle after observation still $22'$ E. Steady slight wind near S. W.

20th Dec.—From $\frac{1}{2}$ past 8 P. M. till 11 P. M., a very splendid Aurora continued, with periodical obscurations and revivals, over a dense cloud resting on, and capping the summits of the North hills. Aurora never getting higher than 20° . Rest of the sky entirely clear of clouds, and slight steady wind at W. Therm. 25° . Needle not affected.

21st Dec.—8 P. M. Intensity $225''$. Therm. 27° . Ground covered with snow.

22nd Dec.—I have been informed, this day, by the Rev. JAMES PAULL, minister of Tullynessle, that on the 20th of Dec. about $\frac{1}{4}$ past 9 P. M. he saw the Aurora remarkably bright, near the zenith, at his house, about 2 miles N. of this place, and I am permitted to use his name for the fact.—8 P. M. Intensity $224''.75$; $225''$. Therm. 28° .

23rd Dec.—8 P. M. Intensity $225''$. Therm. 30° .

24th Dec.—8 P. M. Intensity $225''$. Therm. 30° .

25th Dec.—8 P. M. Intensity $224''.5$; $224''.75$; $224''.75$. Therm. 29° .

I hope the Royal Society will find in the above observations, and in those I transmitted to you on the 15th, a settlement of the much agitated question regarding the disturbance of the magnetic needle by the Aurora borealis. Mr. DALTON was the first, as far as I am acquainted, who observed that the streamers direct their upper extremities to that point in the heavens to which the dipping needle is directed, and that the arches they form are at right angles to the magnetic meridian; but the definite order in the southward progress of the fringes of streamers not having been then ascertained, those circumstances under which alone it now appears that the magnetic needle is disturbed, were for a time overlooked; and results apparently the most opposite were announced by different observers of distinguished skill and reputation.

A proper value will now be put on the results obtained by Captain FRANKLIN and Lieutenant Hood, chiefly at Fort Enterprise. They observed a remarkable disturbance of the needle when the Aurora passed the zenith ; that is, when the fringes came into the plane of the dip, which is there $86^{\circ} 59'$. But the full admission of this fact does not invalidate the results of an apparently opposite nature obtained by others, or their importance. The observations I made on the 21st, 22nd, and 26th of September, 1st, 3rd, 11th, and 25th of October, and the 17th, 18th, and 19th of November last, and now of the 20th December, show, that with very brilliant Aurora, there is no disturbance of the needle, if the fringes do not come into the plane of the dip.

It is evident that as the needle is affected in those places only where the fringes are in that plane, observers in different latitudes may obtain very discordant results on the same evening. The numerous observations collected by Mr. DALTON, of the appearances of Aurora on the 29th March, 1826, (Phil. Trans. 1828,) prove that many fringes of streamers may be parallel to each other at remote distances ; and the observation, by the President of the Royal Society, of a luminous arch in Cornwall, 29th September, 1828, simultaneously with a remarkable Aurora of many arches over the whole of Aberdeenshire, proves that the meteor is sometimes active over a space nearly coincident with the extent of this kingdom ; and we have no reason to suppose it may not extend often much further. There might therefore be an extensive succession of observations of disturbance and non-disturbance of the needle, at the same instant, from N. to S., over many degrees of latitude. Next to the discovery of the truth, it will give me the highest satisfaction if the Royal Society shall be of opinion, that the result of the observations they have enabled me to make, is to reconcile the conflicting statements made regarding this matter, leaving unimpeached the accuracy of all the observers.

The observations of the intensity, on the 19th December, lead now more plainly to the inference, that it is decreased under the influence of an arch of Aurora in the plane of the dip ; but the indications of decrease are too small to be fully confided in, until after a long series of similar results.

I consider Mr. PAULL's observation on the evening of the 20th December, viewed in conjunction with mine, of great importance in various respects. The same Aurora that I saw here under an angle not exceeding 20° high, he saw at

the Manse of Tullynessle very near the zenith. Now the Manse of Tullynessle is about one point E. of due N., distant from this place little more than two miles in a direct line. It is in a narrow side valley that enters northward into a ridge of hills, the nearest summits of which are nearly two miles from here, about the N. point of the magnetic meridian. These are the summits that were capped by the clouds, to the region of which the Aurora was confined the whole evening. A line drawn over them at mag. E. and W. would pass very nearly over Mr. PAULL's station. The height therefore of this particular Aurora at its upper extremities, did not exceed 4000 feet above the level of this place.

In my paper on the Aurora borealis, which the Royal Society honoured with a place in their Transactions of 1829, I stated "that I have here seen the meteor much more frequently in the form of a light near the northern horizon, than in any other form." Mr. PAULL's observation has convinced me, that the true place of this light near the horizon is often no other than the nearest mass of hills to the north.

If any doubt had yet remained regarding the height of the region occupied by the meteor, this observation would have determined the point. The merit of first accurately ascertaining that region is due to Lieutenant Hood and Dr. RICHARDSON, by their observations at Cumberland House and Basquiaw Hill. It is the region immediately above that of the clouds, and of course varies much in height with different states of the atmosphere. Although this region was very low on the 20th December, it is, we know, at times several miles high, agreeing with the observations of those distinguished travellers. I have seen the Aurora here when the height of the clouds could not be estimated at less than two or three miles; and I state this again more precisely, because I understand what I had formerly said, has, by some persons, been misunderstood to imply, that its height never exceeds six or eight thousand feet.

Captain FRANKLIN and Dr. RICHARDSON first observed also the connection of the Aurora with the formation of clouds. The latter even says, "I am inclined to infer that the Aurora borealis is constantly accompanied by, or immediately precedes, the formation of one or other of the various forms of cirro-stratus." He could not however determine whether the Aurora was dependent on the formation of the cloud, or the formation of the cloud on it. I conceive the

observations of the 20th December throw a satisfactory light on this subject, and shall now briefly state the conditions of the phenomena of that evening, and their localities, which lead me to this conclusion.

The mass of hills, named Coreen, to which both the clouds and the Aurora of that evening were entirely confined, is eight or ten miles long from E. to W., and about four miles broad in some places from N. to S. It is nearly bisected by the magnetic meridian of this place, which cuts off the broadest and highest part of it to the W. About twelve or fifteen square miles rise above the limits of cultivation; that is, about six or seven hundred feet above the bottoms of the conterminous valleys; and some of the summits attain an elevation of nine hundred and one thousand feet.

On the W., a little by S., of this mass of hills, there extends for eighteen or twenty miles a succession of valleys of considerable width, all bounded on the S. and N. by high lands of great extent, and separated from each other by comparatively low eminences. Through these the river Don flows from W. to E. On descending this succession of valleys with the course of the river, the Coreen hills are seen directly in the line of them, and apparently shutting them nearly up at the E., the extension of the low ground turning there, for some distance, suddenly N. and afterwards E., by the N. side of these hills; and the river, on the contrary, when it reaches these hills, turning several points S. of its former course, and entering this valley of Alford at its N. W. corner, by a very narrow defile between Coreen and another hill on the S., of nearly equal elevation but comparatively little extent, which is placed more in the direction of the general outline of the high lands bounding the valleys on the south.

We have then, in the situation of the Coreen hills, a most satisfactory explanation of the formation of clouds over them on the 20th December, in well established principles independently of the Aurora. The wind coming steadily the whole evening from W. carried the air out of the upper Don valleys, (where, at a comparatively low elevation, it was nearly saturated with aqueous vapour, to which the river in its long course would much contribute,) over the surface of Coreen; that is, lifted the whole mass several hundred feet perpendicularly, and the diminished pressure and consequent expansion lowered its temperature to the point of saturation.

As the Aurora was entirely confined to the region of the cloud, the cause of

the formation of which we can thus otherwise clearly trace, we are surely justified in considering it as an effect of the condensation of vapour; and as the evaporation and condensation of the aqueous fluid are ascertained agents in developing electricity, the meteor must be considered as a peculiar manifestation of the electric fluid *.

The parallelism of the streamers with the dipping needle; the position of the fringes at right angles to the magnetic meridian; the movement of these fringes away from the N. magnetic pole, and their effect on the needle when they come into the plane of the dip,—all prove it to be equally a magnetic phenomenon; so that we here find another relation between the electric and magnetic influences.

I conceive the result of these observations coincides with many discoveries of a very recent period, to show that we are on the point of being compelled to resolve the long received theory of the magnetic action of the nucleus of the earth, into a peculiar influence of its atmosphere and superficial electricity.

Alford, February 11th, 1830.—Between January 10th and 20th, several series of observations of the intensity of the needle were taken at 8 p. m. Therm. uniformly near 30°; and 50 vibr. very uniformly in 225".25. [It thus appears that the annual increase of the intensity was greatest in the end of December.]

January 25th.—No Aurora was seen since 20th December till this evening, when for about 3 hours from 7 p. m. there were seen, over many detached clouds resting on the Coreen hills in the N., several low arches and parts of arches of brilliant streamers, rising in succession below one another, and expiring about 20° high. Rest of the sky quite clear. Therm. 30°. Needle not affected. Many falling stars in paths parallel to streamers. None of these meteors were seen during the absence of the Aurora.

January 26th.—A steady gale all day a point or two S. of W. Therm. 34° and 35°. Gale became hard after dark, and much snow melted before next morning. The ground has been covered with snow, of which there have been

* This is in accordance with Mr. DALTON's conclusions, that electricity appears to be a consequent rather than an agent in the formation and decomposition of clouds. (Observations on Meteorology, &c. Manchester Memoirs, Second Series, vol. iv.)

many falls since the 20th December, with a nearly steady frost, generally from 30° to 35° Fahr., but once or twice as low as 12° at sunrise. Wind since that time till now in all points, except W. and S. W.

January 27th.—Again frost and calm. Therm. 30° . Intensity $225''.25$.

January 28th, 8 P. M.—Several low arches of Aurora of great brilliancy, with many streamers over clouds resting on the Coreen hills. Rest of the sky quite clear. Needle steady. Therm. 25° .

$\frac{1}{2}$ past 8.—An arch has come slowly forward and passed the zenith into the plane of the dip; its west part fading as it reaches that position; but the east part from the mag. merid. continuing moderately bright. Needle shifted to $21' 30''$ E. or towards the bright part. Intensity $225''.25$. After this observation, needle on steel point returned slowly to $6'$ E.

5 min. before 9.—Another very bright arch, about 3° broad at the vertex, and extending nearly from the E. to the W. horizon, but narrowing much at its extremities, came forward into the plane of the dip. The light of this very beautiful arch was nearly uniform from end to end. Sky quite clear, when it was in the plane of the dip, excepting over the Coreen hills, where there were still many clouds. Needle on steel point moved incessantly at this time, but irregularly and somewhat fitfully, alternately to E. and W. within the limits of about $30'$ in all. Intensity $226''$. Arch faded slowly about 30° S. of the zenith; and needle on steel point returned to rest nearly at zero.

Many falling stars in paths parallel to the streamers, i. e. to pencils of rays of the Aurora, were they at the same places.

Many low arches rose in succession after this to about 25° above the Coreen hills; some of them with very brilliant streamers. Needle steady. A slight steady breeze a point or two S. of W. set in after 9 P. M. At 11 P. M. therm. 24° .

January 29th.—Therm. 36° . A steady gale all day, a point or two S. of W. till sunset, when it shifted to N., and therm. fell to 30° . 8 P. M. Intensity $225''.25$.

February 6th and 7th.—Steady moderate frost till now, when there occurred a terrible storm at S.S.E. with a heavy fall of snow. At 8 P. M. of 6th, therm. 27° . Intensity $225''.5$.

It will be seen that the observations now detailed confirm the result of those I formerly sent, viz., that the magnetic needle is disturbed by the Aurora only

when the fringes come into the plane of the dip. I employ the term fringe, which I first used in my paper on the definite arrangement and order of progress of the meteor, as the term arch can have reference properly to two only of its dimensions, while fringe may include the idea of all the three.

The observations of the 28th January lead to the conclusion, that the N. pole of the needle (meaning the pole that is directed towards the N.) shifts towards the most brilliant end of the fringe. The successive phenomena of that evening were remarkably distinct, giving great facility to accuracy of observation ; and I remember nothing of the kind surpassing them in splendour. The first fringe of that evening, which crossed the zenith, and faded in its W. end as it got into the plane of the dip, exhibited, in the most distinct way, the manner of the progress southward, by the extinction of streamers at its northern face, and the sudden formation of new ones along the whole of its southern face.

After making the attempt, I have found it impracticable to keep any journal in detail, of the falling stars, on account of the great numbers that often occur in the same evening ; but I have not failed to observe them since my attention was directed to them in the remarkable manner I mentioned to you in a former letter*. I have now no doubt whatever that they are a branch or modification of the Aurora borealis. In a vast majority of cases their paths are parallel to the streamers of the aurora, that is, they are directed away from that part of the heavens to which the upper end of the dipping needle points ; and in those cases, comparatively few in number, where this parallelism

* *Date Nov. 11.*—During the course of these observations, my attention has been incidentally directed to another meteor, that of falling stars ; and the conclusions to which my observations of these phenomena (as yet I must acknowledge very limited) have uniformly led, I have no doubt you will acknowledge to be interesting. I would have introduced this subject to you in my last, had I not felt it proper to wait till the views regarding them, which had at that time opened to me, should be ascertained to be correct or not, by some continuance of observation.

On the evening of the 21st of September at 10 $\frac{1}{4}$ P. M. there occurred an Aurora, rising above the northern horizon in detached groups of bright streamers and nebulous patches of light. Many flashes of sheet lightning were seen, during and after its continuance, in the western part of its space ; and in the eastern part several falling stars descending among, and having paths quite parallel to, the streamers. I could not quite satisfy myself whether the course of the sheet lightning was vertical in a downward direction, on account of its suddenness ; but that was the impression to which my observations chiefly led. But the correct parallelism of the paths of the falling stars to the streamers led

is departed from, the paths can generally be referred to the planes of the fringes of the Aurora, and, within these, to lines at right angles to the streamers. I have even seen a succession of three or four or more falling stars, at momentary intervals, whose paths were all wholly within the plane of a fringe, or such a narrow zone as an elevated fringe would occupy ; and again, after a considerable interval, have seen a similar succession in a similar zone, further S., as if the planes in which they are active moved southward like the fringes of the Aurora. But the circumstance which perhaps most convincingly connects them with the Aurora, is their occurring in great numbers on those evenings when it is visible, and their rareness at any other time, a fair example of both which cases is to be found in the foregoing journal.

It will be perceived from this and my former communications, that the Aurora precedes and accompanies W. and S. W. gales, which are generally the hardest we experience. In the absence of more direct observation, I may be permitted at present, although it is not strictly legitimate, to refer to the popular belief, that the falling stars also are indicatory of hard gales.

I think there is now no doubt that the horizontal intensity is affected by the Aurora borealis, as the indications are uniformly on one side, and longer practice has given me more confidence in the correctness with which I am enabled to measure the times.

me to examine the direction of those I have seen since. They are now very numerous, and, without any exception, their paths have been directed from a point near the meridian, within the limit of from 10° to 20° south of the zenith. These meteors, too, have been most frequent on those evenings when the Aurora borealis appeared, with the exception of the evening of the 16th October, when there was no Aurora, but a great number of falling stars. The state of the weather and wind that night was, however, such as led me to anticipate and make preparation for a display of the former. The paths of those falling stars I have seen near the zenith have been all short in comparison with those seen on the same night lower down.

These observations of mine have been too few, and limited to too short a period of time, to give confidence in the inferences which are to be deduced from them ; but being now put into your possession, they will either soon be confirmed or their partial character shown : but it may surely be worthy of inquiry, whether the falling stars of southern latitudes are the equivalents of our Aurora borealis.

March 24th, 1830. (Journal continued.)—Therm. 45° , observed a remarkable Aurora. A bright fringe having a little deficiency near its vertex, but reaching low towards each horizon, and about 4° broad, is near the plane of the dip. To the northward of this, and crowding up to it with intervals only of about 3° , 4° , and 5° , many fragments of another fringe, some of them 10° or 20° long from E. to W., others much shorter; the general breadth of these varying from about 4° to 6° or 7° . N. of these again other fragments of a fringe or fringes, having their most lengthened dimensions very perceptibly in an E. and W. direction; and the whole northern part of the sky, down to a long dense cloud stretching the length of the Coreen hills and elevated only 8° or 10° above them, is filled with brilliant streamers, at times presenting apparently inextricable confusion, and at other times partial appearances of arches. No clouds in the region of the Aurora, nor southward of it, with the exception of one on the S.W. horizon. A bright nebulous light about 15° high along the whole S. horizon.

The whole lights in the N. part of the sky made a rapid progress southward; and the manner of this progress was repeatedly finely exhibited in the fringes and fragments that had reached or passed the zenith, by the extinction of streamers at their northern faces and the formation of new ones at their southern faces. The advanced southern fringe expired when it had reached about 25° S. of the zenith; and all did so, either when they attained a similar angle S., or before they had gone so far. The confused mass of streamers in the N. as they came forward in succession to the zenith, and passed that point, unfolded themselves into narrow zones of light at right angles to the magnetic meridian, or very nearly so; for there was occasionally a small deviation from parallelism among themselves. These zones were more numerous than I have seen on any evening before, and were separated from each other by less intervals, sometimes not exceeding 3° or 4° , sometimes however 15° or 20° . There were among them two complete and very lengthened fringes, besides the one first described; but the larger proportion consisted of only fragments of similar fringes, cut short more or less in their E. and W. dimensions.

The needle on the steel point, from the first moment of observation was very unsteady, shifting sometimes more slowly, and sometimes more rapidly and

fitfully, within the limits of about 50° , in the most extreme case, on each side of the ordinary magnetic line.

5 min. past 9 P.M.—With a very lengthened fringe in the plane of the dip, varying much in intensity of light from end to end; the needle on the steel point shifted to 32° W.; I then made trial of the intensity with the needle, and observed the arc of oscillation, at the conclusion of 50 oscillations, much less than I have uniformly before observed it. Time of 50 oscillations $224''$. Dropt the needle on steel point, and found it now (a few seconds only after concluding the observation) $25'$ E. Repeated the trial of the intensity immediately, and again found the arc of oscillation at the conclusion greatly diminished. 50 oscillations in $224''.25$. Needle instantly dropt on the steel point now returned to $34'$ W.

Having examined the needle on the steel point for some considerable time, and the extremely irregular nature of its movements, under the influence of succeeding fringes coming into the plane of the dip, I conceive the true explanation of the irregularity in the extent of the arcs occurred to me. The arc of oscillation being bisected by the line of the magnetic force, when this line changes its direction suddenly, as is indicated by the needle on the steel point, the arc is either enlarged or diminished suddenly at the same time, according as the line shifts from or towards that of the needle, at the moment when it has completed an oscillation, to return in another; and the time of the oscillations is thus sensibly changed.

This conclusion might indeed have been drawn from the previously observed phenomena, but did not occur to me till the experiments of this evening brought it into view.

Besides changes in declination, the needle on the steel point often exhibited a slight vertical movement and tremor, indicative of a change of the dip, and showing thus another impediment to an accurate determination of the intensity.

At a quarter to 10 P.M. the region occupied by the Aurora was extensively obscured by a haze, preventing further good observation.

Several circumstances occurred this evening confirming the views that the observations of the 20th December last had led to; viz. "That the Aurora is dependent on the condensation of vapour." It is familiar to every one, resident in a mountainous country, that clouds, even during hard gales, continue appa-

rently stationary over the higher summits, and present themselves in these situations when the rest of the sky is clear. The explanation is quite simple. The lower saturated strata of air being carried over the summits, the diminished pressure and consequent expansion lower the temperature to the point of condensation; and as the air in its progress again descends, a reverse effect occurs, and the vapour is again dissolved. A cloud of this kind appeared to rest the whole time of the appearance of the Aurora over the line of the Coreen hills, little elevated above them, and appearing to furnish, as it were, the base of the bright Aurora in the northern part of the sky.

It has been stated that a detached cloud rested on the S. W. horizon; and the description of the circumstances attending it has been deferred till now. It continued apparently stationary all the time of the observations from 20 minutes to 9 till a quarter to 10; and I had no difficulty in referring it with certainty to the summit of a large hill about six miles from this place, having considerably more elevation than the Alford hills, and standing several miles apart from any summit of nearly equal height. Now over the top of this cloud, which was quite free of the northern Aurora, and also of the nebulous Aurora at the S. horizon, there continued the whole time a very bright nebulous light. The large hill referred to is not itself visible from this place, on account of a high ground about a mile distant.

I have little doubt also that the nebulous Aurora at the S. horizon, which likewise continued the whole time, ought to be referred to a range of hills extending E. and W., about seven miles distant, and nearly as high as the Coreen hills. A high ground about three quarters of a mile distant conceals these hills from view, and would also conceal clouds over them, as high as those above the Coreen, on this evening.

It would thus appear that the pencils or bundles of parallel rays of the Aurora, denominated streamers, and whose longitudinal dimensions always show themselves parallel to the dipping needle, become indistinct at the distance of a few miles, being blended and softened down into a nebulous light by the refraction and haze of the atmosphere.

The wind the whole time was a rather strong gale a point or two S. of W. There have been very severe gales from the same quarter for three days past.

I have this evening again seen several falling stars during the continu-

ance of the Aurora, having seen none since I saw it last. Four were over the Coreen hills, and the paths of all were nearly but not quite parallel to the streamers. As if in correspondence with the great brilliancy of the Aurora, they were very large and bright, fully equal at least to Jupiter.

My attention having been sometimes directed to the diurnal variation of the needle, for the purpose of ascertaining whether any interference might be expected between it and the influence of the Aurora, I have been led by many observations (of the whole of which indeed I have no regular notes, but only of a few,) to conclude that the quantity of the variation depends on the brightness or gloominess of the weather. Thus, on the brightest day that has occurred since I received the apparatus, the 2nd of October 1829, therm. 52° , the diurnal variation at noon was $26' 20''$ W. On the two gloomiest days that have occurred, the 3rd and 4th of December, 1829, therm. about 42° , the diurnal variation at noon was $3' 20''$ and $3' 40''$ respectively. Again, some observations in the month of January last, on bright days, when yet the earth derived little or no heat from the sun, owing to a close covering of snow and a hard frosty wind,—and others, on bright days likewise, when the earth, much cleared of snow, imbibed much heat,—would lead me to believe, that the direct radiating heat of the sun has more effect than the light in causing the increased variation, when the state of the earth's surface is such as to imbibe that heat.